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PRODUCTION OF HEAT-SHIELDING GLASS USING DUST FROM ELECTRIC FILTERS

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Heat-shielding glasses have been produced using dust from electric filters as the colorant agent. The introduction of such pigment makes it possible to obtain glasses with different spectral parameters.

Heat-saving glass was developed to reduce heat losses. The use of such glass in industrial and residential buildings makes it possible to lower the power consumption in heating by 30 – 50% [1].

Heat-shielding properties can be imparted to glass either by applying different coatings on the glass surface or by bulk tinting of glass. Standard silicate construction glass well transmits infrared rays with a wavelength up to 2000 nm. An abrupt decrease in the transmission of the IR spectrum is observed in this glass in the range of 2000 – 3000 nm, and at 5000 nm, the transmission drops virtually to zero. At the same time, the solar radiation reaching the Earth includes IR rays with a wavelength of 750 – 2500 nm. Thus, window glass virtually does not inhibit and well transmits all thermal solar energy [2].

To make silicate glass inhibit thermal rays, chemical compounds capable of absorbing and reflecting the IR spectrum range are introduced in the glass composition. Such compounds include copper, cobalt, nickel, and iron oxides. The presence of copper, cobalt, and nickel oxides in glass decreases not only IR-radiation transmission but the visible light transmission as well, whereas iron oxide in a certain state absorbs IR rays without significant absorption of the visible spectrum range. Considering that iron can form various compounds with different capacity for absorption and reflection of IR rays, numerous publications are dedicated to the subject of tinting silicate glass using iron compounds [3, 4]. It is established that glasses containing bivalent iron oxide FeO have the highest capacity for IR ray absorption. Glasses with a low content of Fe_2O_3 virtually do not absorb IR radiation.

The Belgorod State Technological Academy of Construction Materials carries out research to identify the possibility of using industrial waste generated by the mining, metallurgical, cement, and chemical industries in glass technology [5, 6]. Arc melting of concentrated iron ore causes dusting of the material. Part of the dust is carried out of the furnace with waste gases and is trapped by electric filters. For instance, the Oskolskii Electrometallurgical Works annually generates around 700 tons of dust. Qualitative elemental analysis employing a spectroscan indicated that such dust has a rather constant composition. The quantity of the elements was estimated from the peak intensities and amounted to (%): 42.8 Fe, 0.145 Pb, 0.789 Zn, 4.44 Mg, 1.66 Cr, 0.0159 Cu, 0.005 Ni, and 0.0118 Co. The x-ray phase analysis of dust established that its only crystalline phase is mainly represented by magnetite Fe_3O_4. The main fraction of the dust contains grains of size 20 – 30 μm (22%), 30 – 40 μm (20%), 40 – 50 μm (15%), and 50 – 60 μm (11%), and the finely dispersed fraction (below 15 μm) constitutes around 20%.

The preliminary studies of the chemical composition of dust suggest that it can be used as a colorant agent in glass technology. Since the intensity of the iron-related peaks differs by an order of magnitude from the peak intensities of other elements, it can be assumed that iron oxides will make the main contribution to the tinting process.

The properly melted heat-absorbing glasses containing FeO should have a blue color. The formation of a yellow color to a large extent is related to the formation of sulfurous iron. Sulfur is always present in raw materials, and even an insignificant content of sulfur in the glass composition can produce a yellow color. The emergence of sulfurous iron is observed in every case of excessive use of reducing agents, even when pure materials are used for glass melting. It should be noted that equilibrium of FeO and Fe_2O_3 is flexible and depends on the melting conditions and on the composition of the glass batch and raw materials and their redox potential. Thus, the amount of colorant is selected taking into account the required transmission of visible light, the degree of IR radiation absorption, and the required glass thickness.

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TABLE 1

Mixture	Mass content, % colorant	Mass content, % reducing agent	Melting conditions	Glass tint
1	2.0	–	Oxidizing	Green
2	1.0	–	The same	Greenish-blue
3	0.5	–	" "	Light blue
4	1.0	1.0	Reducing	Bluish-green
5	2.0	2.5	The same	Brown

TABLE 2

Glass	Transmission, %, in range, nm: 400 – 700	900 – 1100	2500 – 2800
Green*	45	20	15
Blue*	45	10	37
Light blue*	45	25	55
Greenish-blue*	30	7	25
Brown*	15	5	20
Clear**	90	65	78
Brown**	28	15	49
Blue**	76	27	62

* Experimental sample.

** Industrial sample.

The glass taken as the base in this study was float sheet glass of the following composition (wt.%): 73.0 SiO_2, 1.0 Al_2O_3, 0.08 Fe_2O_3, 8.6 CaO, 3.6 MgO, 13.4 Na_2O, and 0.32 SO_3. The batch was prepared using VC-050-1 sand from the Tashlinskoe deposit, Belgorod chalk (GOST 17498–72), soda (GOST 10689–74), dolomite (TU 21 RSFSR 474–28), and feldspar concentrate from Vishnevogorskii Concentration Works. The colorant (dust from electric filters at the Oskolskii Works) was introduced above 100%. In order to create reducing conditions in melting, activated coal was additionally introduced in the batch. The quantity of the reducing agent was selected experimentally, and the quantity ensuring blue tinting in glass was taken as the optimum one.

The batch was melted at a maximum temperature of 1450°C in a laboratory electric furnace in corundum crucibles of 100 ml capacity; the melting lasted 10 h. Additional charging of batch in the form of briquettes was implemented at temperature of 1400°C. All glasses were well melted but not sufficiently clarified (small bubbles were visible), which can be attributed to inadequate mixing in the laboratory melting conditions. The melted glass was not aggressive to the crucible material and was easy to mold (casting in metal molds). The annealed glass samples were ground and polished by a set of grinding powders to obtain a plane-parallel surface. The glass properties were determined according to the standard methods. The variations in the melting conditions and the pigment content are shown in Table 1.

TABLE 3

Parameter	Glass* green	blue	light blue	greenish-blue	brown
Total transmission, %	38.5	52.0	64.0	44.5	10.0
Reflection, %	6	2	4	6	4
TCLE, 10^{-7} K^{-1}	89	91	90	90	90
Microhardness, MPa	6652	6652	6648	6650	6652
Density, kg/m^3	2522	2520	2510	2500	2522
Refraction index	1.52	1.52	1.51	1.51	1.52

* All glasses in water resistance belong to hydrolytic class III.

Mixtures 1 – 3 were melted under normal conditions, with the pigment quantity varying from 0.5 to 2.0%. The maximum amount of pigment produced green-colored glass, which was mainly determined by the content of iron(III) oxide in electric filter dust. The glass composition changed to light blue when the pigment content was 0.5%. This is determined by the prevalence of Fe^{2+} ions, as a result of the fast rise in the melting temperature up to 1500°C.

Glass 5 melted with activated coal added to the batch, and with a pigment and reducing-agent ratio equal to 2.0 : 2.5, it had a brown color, which can be accounted for by the excess of the reducing agent and the formation of sulfurous iron. With a pigment to reducing-agent ratio equal to 1 : 1, the glass has a bluish-green color.

Thus, in selecting the optimum content of the colorant (electric filter dust) and the optimum ratio of the colorant and the reducing agent under reducing melting conditions, it is possible to obtain blue bulk-tinted heat-shielding glass.

The main service parameters of the synthesized glass include the integral and spectral light transmission, transmission in the IR spectrum, and the reflection coefficient. The thickness of the blue and brown industrial glasses was 5.5 mm, and the thickness of the other glasses was 6.5 mm.

The spectral characteristics in the visible and near IR ranges were analyzed on a Specord SF-26 device. Compared to the standard sheet glass, the spectro-float glass transmits up to 45% of rays in the visible spectrum range (Table 2). The increased transmission of blue industrial glass (76%) can be accounted for by the smaller thickness of the sample.

The study of heat-shielding properties on a Specord 75 IR device in the range of 2500 – 25,000 nm demonstrated that all experimental samples exhibited heat-shielding characteristics in the near and oscillation IR spectrum range (Table 2). The greatest heat-absorbing capacity was exhibited by the green (composition 1) and brown (composition 5) glass: their absorption of IR rays was 80 – 85 and 80 – 90%, respectively. These glasses contained an equal quantity of the pigment but were melted under different redox conditions. The heat-shielding properties of compositions 2 – 4 are comparable to the heat-shielding properties of industrial sheet glass and range within the limits of 45 to 75% absorption in

the IR range. The physicochemical properties of experimental samples of thickness 6.5 mm are shown in Table 3.

It can be seen that the use of dust from electric filters as a colorant does not deteriorate the main physicochemical properties of heat-shielding glasses, and the dust itself is an inexpensive technological material for production of glasses with different spectral parameters.

The experiment established the possibility of using dust from electric filters for the production of differently tinted heat-shielding glasses, depending on the melting conditions. The blue heat-shielding glass has sufficient transmission in the visible spectrum range, which is essential for sheet glass. The brown and green glasses can be used in production of glass containers for food and drinks.

The electric filter dust from the Oskolskii Electrometallurgical Works is industrial waste (700 tons per year) and constitutes an inexpensive material, which does not need additional preparation to be used in the glass industry. Utilization of this waste will free fertile land territories and improve the environmental situation.

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